1971

A Study of Silver Recovery Processes and Comparative Classification of Silver Recovery Equipment for the Graphic Arts Industry

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A STUDY OF SILVER RECOVERY PROCESSES AND COMPARATIVE CLASSIFICATION OF SILVER RECOVERY EQUIPMENT FOR THE GRAPHIC ARTS INDUSTRY

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Printing Management, South
Dakota State University

1971

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This thesis is approved as a creditable and independent investigation by a candidate for the degree Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

ACKNOWLEDGMENTS

The author wishes to extend his appreciation to the many respondent manufacturers and suppliers of silver recovery equipment for their time, effort and materials needed to make this study possible.

Special thanks is given to Dr. George H. Phillips, Head of the Department of Journalism and Mass Communication, and Associate Professor James F. Scotton, for their valuable guidance and assistance in carrying out this study.

The author is particularly indebted to his parents, Mr. and Mrs. Raymond Bittner, for their unending patience, encouragement and financial support which were needed to complete this thesis.

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CHAPTER I

INTRODUCTION

Statement of the Problem

Silver is a metal with a long and interesting history. It was one of the first metals discovered and worked by early man, and has been recognized as a standard of value for thousands of years. Although gold, held mostly by kings and priests, was the first metal to be recognized as a standard of value, evidence from graves has shown that man in Southern Europe and the Near and Middle East was found to have endowed with silver ornament and even to have used the metal in bulk as a token of wealth exchangeable for goods, services, or ownership.[1] Silver's brilliant white color, resistance to corrosion, and relative scarcity created a demand for it both as ornamentation and as a store of wealth, and brought about its eventual distribution throughout the world.

Today, silver is still used extensively in such items as jewelry and tableware. However, with the growth of modern industry, many important technical uses have

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1 Donald McDonald, "History of Silver," in Allison Butts, ed., Silver Economics, Metallurgy, and Use (New Jersey: D. Van Nostrand Co., Inc., 1967), pp. 1-15.

been found. For example, the unique electrical properties of silver make it essential to a wide variety of electrical and electronic equipment. The technical use with which this paper is concerned, is the ability of certain silver compounds to change upon exposure to light. This is the reaction upon which the whole photographic process depends, and therefore, that which makes the modern photographic industry possible. The result of these and many other modern uses has been a severe shortage of silver, in that more silver is being used than is presently being mined. According to one source, "The Free World uses approximately 350 million Troy ounces of silver annually in industrial products. New mine production is in the vicinity of 235 million Troy ounces, leaving a deficit of 115 million Troy ounces which must be supplied in some way."[2]

Since over two-thirds of newly mined silver is produced as a by-product of copper, lead, and zinc mining, production is influenced by the demand for these base metals. The major sources which make up the deficit of silver are demonitized coinage, which contains a large quantity of previously mined silver, and salvaged industrial wastes.

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2 Anonymous, "Recovering Silver From Photographic Materials," (New York: Eastman Kodak Company, 1969), p. 3.

Table 1 shows that the photographic industry consumes almost one-third of the total silver used by industry in the United States.[3] It has been estimated that

TABLE 1

INDUSTRIAL CONSUMPTION OF SILVER IN THE UNITED STATES BY MAJOR CATEGORY

Category	Per cent
Photography	32
Electrical & electronic (including batteries)	31
Silverware and jewelry	17
Brazing alloys and solders	13
All others	7
Total	100%

approximately two-thirds of this silver is potentially recoverable from used photographic fixers, films, and papers. Silver recovery therefore, represents a significant means for conserving silver as an important natural resource. For the user of photographic products who does not feel that the conservation of natural resources is his concern, there are other reasons for recovering silver from photographic wastes.

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3 F.H. Wemple, "The Silver Market," in Butts, p. 53.

Today, more than ever, graphic arts firms are faced with a need for increased sales, low cost production, and profit maximization. These factors have forced the management teams of graphic arts firms to take a closer look at costs of materials. With the cost of photographic products constantly rising, these firms are becoming more aware of the fact that recovering silver means a substantial savings of some of the expenses of operation, provided that the recovery can be effected simply and economically. And it can be.

From 1960 to 1969, silver prices varied from a low of 90 cents to a high of $2.56½ per Troy ounce.[4] Until 1967, the price of silver was, in effect, set by congressional action which authorized the U.S. Treasury to buy and sell silver at a fixed price. This policy was changed in 1967, and an essentially free market in silver was established. As a result, the price of silver responded to the market demand and speculative buying. It reached a high of $2.56½ per Troy ounce in 1968. Since that time, it has declined. During 1969, the monthly average price fluctuated from about $1.62 to $1.98 per Troy ounce.[5]

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4 Annual Report of the Director of the Mint, for the Fiscal Year Ended June 30, 1969, (Washington D.C. : U.S. Government Printing Office, 1970), p. 113.

5 Annual Report of the Director of the Mint, p. 112.

With the price of silver averaging around $1.80 per Troy ounce, a typical gallon of exhausted fixer may contain a gross silver value of as much as $2.00. After deducting the labor involved, shipping and refining charges, and the amortization of the silver recovery equipment, a firm can expect to save $70 or 7% for every $1,000 worth of film consumed; furthermore, processed films which no longer have any record value may have a silver scrap value of as much as 15 to 35 cents per pound. The actual value of the scrap film varies with the nature of the films, the quantity available, the cost of shipping the scrap to the refiner, and the market value of silver at the time of refining.

One manufacturer of equipment that reclaims silver from scrap film states that its equipment, "Requires only one man-hour per day to reduce an 800 pound load of film to about 32 pounds of ash (2 cubic feet) with an approximate value of $400 in silver."[6] Tables 2 and 3, (on the next page) give more accurate figures with which a firm could determine its potential savings by recovering silver from processing solutions, scrap film and paper.[7&8]

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6 "The Silver Drain," Modern Lithography, Vol. 39 (January 1971), p. 25.

7 "Recovering Silver," p. 8.

8 "Recovering Silver," p. 10.

TABLE 2

QUANTITY OF SILVER POTENTIALLY AVAILABLE FOR RECOVERY FROM EXHAUSTED FIXING SOLUTION

Type of Material Processed in Fixing Solution	Units	Troy Ounces per 1000 units
Lith-Type Films (50% exposed)	8X10-in. sht.	3.5 to 5.5
Continuous-Tone Films	8X10-in. sht.	4.5 to 6.0
Stabilization Papers	1 sq. ft.	1.5 to 2.5

TABLE 3

QUANTITY OF SILVER POTENTIALLY RECOVERABLE FROM EXPOSED AND PROCESSED BLACK AND WHITE PHOTOGRAPHIC MATERIALS

Type of Material	Troy Ounces per pound of scrap
Lith-Type Films (50% exposed)	.15 to .25
Continuous-Tone Films	.05 to .15
Photomechanical Papers	.015 to .03

It's easy to see that the use of silver reclaiming equipment can pay special dividends to the printer. By reclaiming silver, a lithographic printer can reduce operation costs, increase the quantity of available silver, minimize rising costs of photographic supplies, and help to

insure a steady availability of such supplies. In addition, there is still another reason for the printer to recover silver from his photographic wastes.

There is an added benefit in the fact that silver is classified as a water pollutant. For the printing industry, the day is rapidly approaching when there will be no escaping the wrath of the public and subsequent enforcement action by local pollution control officials. It is no longer a matter of whether or not anti-pollution devices will be required, but rather a question of when they will be required.

The lithographer who traps silver in his plant keeps it from eventually entering rivers and streams. One manufacturer of silver recovery equipment observes that the silver nitrate used in photographic emulsions "is a deadly poison" and that, as government anti-pollution regulations get tougher, there may be rigorous measures against discharging it into rivers.[9] It is of little importance whether a photographic products user helps control water pollution out of fear of future government regulation or because he is genuinely concerned about the quality of his environment. What is of prime importance, is that every firm become acutely aware of the consequences of polluting

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9 "The Silver Drain," p. 19.

our water supply, and that every firm do its part in pollution abatement.

To summarize these first few pages, printers using photographic products are faced with three problems: (1) a severe shortage of silver, an essential raw material in the photographic process; (2) rising production costs due to the ever increasing cost of photographic supplies, and (3) government regulation of disposal of photographic wastes due to public concern about water pollution. Combined, these problems should convince those in the graphic arts industry that the time has come to equip for silver recovery.

Objectives of the Study

The first objective of this investigation is to alert the graphic arts industry to important problems now facing those who use photographic materials, and to show the importance of silver recovery as an effective means of solving these current problems.

Another objective of this study is to explain the several silver recovery processes so that the potential buyer of silver recovery equipment may understand exactly how each process works. This area of study would also explain where silver is to be found; how a firm can estimate its potential savings from silver recovery, and how a firm can determine the silver recovery method best suited for

its particular plant. Also included in the study would be the different applications of silver recovery equipment and the advantages and disadvantages of each.

The final objective of this study is to supply those firms considering the installation of silver recovery equipment with comprehensive information on many different brands and models of silver recovery equipment now available.

CHAPTER II

METHODS EMPLOYED IN THE STUDY

The methods employed in this study involved a comprehensive gathering of information pertaining to silver recovery processes and the equipment now available for recovering silver from photographic materials. Data accumulated were divided into the following three categories: (1) Information extracted from books and periodicals; (2) Reports, papers and pamphlets received from organizations involved in the manufacture and distribution of photographic materials and/or silver recovery equipment, and (3) Information drawn from questionnaires returned by manufacturers and distributors of silver recovery equipment. Data obtained from the sources noted in the third category included information describing silver recovery equipment presently available to the graphic arts industry. Also included in this category are the characteristics, capabilities, and limitations of each brand and model of silver recovery device.

Information thus gathered comprises the content of chapters 3 and 4. Chapter 3 presents a general yet comprehensive explanation of the three major processes used to recover silver from photographic materials. In this

chapter the author attempts to explain not only the basic principles of silver recovery, but also how a firm can estimate its potential savings from silver recovery and how to choose an appropriate recovery method.

Chapter 4 presents a comparative classification of devices currently available for the recovery of silver. Listed by brand and model, each piece of equipment is accompanied by its respective data, which enables the reader to compare the characteristics of each piece of equipment.

Review of Current Literature

As stated earlier, the first category of accumulated data was extracted from books and periodicals. Various bibliographical sources were used to compile data in this category. These sources include: (1) The library card-catalog system; (2) The Reader's Guide to Periodical Literature; (3) The Business Periodicals Index, and (4) Graphic Arts Abstracts. Periodical articles too current to be listed in these references were searched-out and found by reading the latest issues of periodicals dealing with the graphic arts and photographic industries. Combined, these references include a bibliography of all relevant articles, books, and reports published regarding silver recovery processes and equipment.

Letters of Inquiry

The initial review of current literature proved to be of great value by supplying the names and addresses of people and organizations in the industry that had a knowledge of silver recovery and its processes. Letters were written to four of these people in an effort to gain first-hand information about silver recovery in general, and to answer certain questions about silver recovery that were raised during the author's initial research. Although the number of replies was relatively small, the two firms that did reply were very helpful and encouraging. A duplicate of the letter of inquiry appears in Appendix A, followed by a duplicate of one of the letters of reply, in Appendix B.

Questionnaires to Manufacturers and Distributors

In order to gather data on individual brands and models of silver recovery devices, a three-page questionnaire was mailed to manufacturers and distributors of silver recovery equipment. The mailing list was drawn from articles in periodicals, advertisements in periodicals, directories for purchasing printing equipment, and names supplied by respondents to the letters of inquiry. Of the 23 questionnaires mailed, returns were received from 18 firms, or 78.26 per cent of those surveyed. A copy of this questionnaire appears in Appendix C.

The questionnaire included 15 questions designed to supply various data on both the organization surveyed and its equipment. Questions about equipment were designed to collect data which would help to describe the characteristics, capabilities, and limitations of individual brands and models of silver recovery devices. Questions 1, 2, 3, 14, and 15 were questions about the organization itself, with the remaining questions dealing with the equipment.

The questionnaire included a statement at its end, welcoming any comments that the respondent might have about the study or the questionnaire. Of the 18 respondents, 10 made comments. Some asked for a copy of the completed study while others offered additional information pertinent to the study or their equipment.

Each of the 23 questionnaires was accompanied by a letter of transmittal and a self-addressed, stamped, return envelope. The letter briefly described the nature of the study and emphasized that a completed, returned questionnaire was important to the success of the study. A copy of this letter appears in Appendix D.

CHAPTER III

THE SILVER RECOVERY PROCESSES

Where is Silver to be Found?

In the general field of lithographic printing, silver is recovered from two main sources. One source is various exhausted processing solutions; the other source is expended processed films, papers, and some printing plates. Deciding whether and/or how to go into silver recovery is a decision that is best made after a review of the basic chemistry of the photographic process.

Silver exists in unexposed films and papers as small silver halide crystals that change when they are exposed, or struck by light. When this film or paper is placed in developer, these light-struck crystals turn black and form the image on the film or paper. Crystals not exposed to light do not develop. They cannot be allowed to remain in the film or paper because, with age, they would darken and ruin the image. The image must be stabilized, so these crystals are removed by dissolving them in a fixing bath. The "fix" includes many ingredients, but the key item is sodium or ammonium thiosulphate (hypo), which dissolves silver halides. As the hypo does this job, the silver compounds accumulate in the fixing

bath, and the capacity of the fixer is exhausted. When this happens, the bath is ineffective and must be discarded.

Films and papers fixed with sodium thiosulphate fixers, which are usually supplied in powder form, have wash properties similar to those fixed with ammonium thiosulphate fixers; however, they are more sensitive to silver buildup and are correspondingly more sensitive to its removal. Removal of silver from this type of fixer keeps the fixing time short and, more importantly, increases the life of the fixing bath considerably.

Fixing baths contain the largest percentage of recoverable silver. For example, when certain black and white films are processed, as much as 60 to 80 per cent of all the silver in the light sensitive emulsion is removed and suspended in the fixer. These figures vary, depending on the type of film and the amount of exposure and development.

In the processing of black and white reversal type films, the largest amount of recoverable silver is dissolved in the bleach bath. The bleach is used to dissolve the silver image while leaving the silver halide intact. The concentration of silver in a used bleach bath is not as great as that found in a typical fixing bath because the bleach requires a relatively high replenishment rate to maintain its effect on the silver image.

In color processing, unlike the black and white reversal process, the silver does not dissolve into the bleach solution. Instead, the silver is converted to a silver salt right in the film emulsion. This silver salt is dissolved in the subsequent fixing bath. Thus, almost all the silver is available for recovery from the fixing bath in the color process.

As mentioned earlier, silver recovery from expended processed films, papers, and some printing plates is also feasible. Almost all black and white films and papers can be utilized for recovery purposes. Certain printing plates also yield appreciable quantities of silver. Recovery methods for such materials will be discussed later in this text.

When to Consider Silver Recovery

There are no hard and fast rules to guide the user of photographic products in determining when silver recovery should be introduced into his operation. The installation of silver recovery equipment is essentially an economic decision. It is influenced by factors such as the current price of silver, the potential value of the silver-bearing waste, and the estimated cost of having the waste processed for silver recovery. Convenience of recovery and the ease with which it can be accomplished are other considerations. According to one manufacturer of

silver recovery equipment, "When the volume of fixer consumed amounts to 150 gallons a year or more and with the price of silver being between $1.50 and $2.00 per Troy ounce, one might consider recovery from solutions if the solutions contain at least ½ Troy ounce of silver per gallon."[10] The cost of recovering silver from fixer will generally run between $.40 and $1.00 per Troy ounce. The more that must be done to get the silver into saleable form the higher the cost of recovery.

For those considering the recovery of silver from expended processed films and papers, some factors to consider are: (1) the silver content per pound of scrap; (2) the ease and convenience with which the scrap can be gathered, stored and shipped or processed; (3) the amount of scrap available, and (4) whether or not the scrap is of a confidential nature. Scrap of a confidential nature should be processed by the firm doing the printing, or by a reliable recovery service.

As a rough guideline, users of photographic products who discard 25 or more pounds of scrap per week on a continual basis, should consider the recovery of silver from sensitized goods if those materials contain as little as .10 Troy ounces of silver per pound of scrap material.[11]

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10 "Recovering Silver," p. 6.

11 "Recovering Silver," p. 6.

How to Calculate Your Firm's Potential Savings

Before purchasing silver recovery equipment, it is advisable to have a trained representative from a manufacturing or distributing firm make a precise estimate of your silver recovery potential. However, you may want to make a preliminary estimate of your own.

As seen in Table 2 on page 6, lith-type films with 50 per cent of the area exposed yield an average of 3.5 to 5.5 Troy ounces of silver per 1000 sheets of 8" x 10" film processed. Also, continuous-tone films yield an average of 4.5 to 6.0 Troy ounces of silver for the same amount of film processed. Using this information, you can arrive at your firm's potential silver yield from the discarded fixer in Troy ounces of silver per year.

To estimate your firm's potential savings from used photographic films and papers, first determine how many pounds of each type of scrap your firm discards annually. After arriving at these figures, multiply each one by the corresponding figures in Table 3. This will give you the number of Troy ounces of silver that can be recovered annually from scrap film and paper.

Determine the current market price of silver by checking financial publications or newspapers such as the Wall Street Journal. By simply multiplying the current market price by your total annual yield in Troy ounces, you have your potential annual savings.

Methods of Recovery from Used Films and Papers

As mentioned earlier, the quantity and value of silver potentially recoverable from exposed processed black and white photographic films and papers is substantial. Usually, such values are expressed in terms of Troy ounces per pound of waste material. The only way to determine the potential value of silver in a given quantity of scrap is to actually assay a representative sample. The value will vary, depending upon the type and thickness of the base material, the type of emulsion, and the silver density on the film. Some rough guidelines for determining the value of scrap film and paper are offered on page 6 of this study. More extensive tables, of the type on page 6, can be obtained from organizations that manufacture photographic products or silver recovery equipment.

Currently there are two different methods of recovering silver from used films and papers. The most widely used method is that of burning, since the silver will remain in the ashes. When using this method, the temperature and rate of burning must be carefully controlled if high recovery efficiency is to be maintained. After burning, the recovery of silver from the resultant ash is accomplished by conventional metallurgical techniques.[12]

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12 C.H. Schack and B.H. Clemmons, "Extractive Processes," in Butts, pp. 57-77.

There are also various chemical treatments used to remove silver from films and papers no longer having any photographic value. Usually these techniques are used only when the film base is to be reclaimed in addition to the silver. Some of the chemicals used to remove silver-laden emulsion from film and paper are sodium hypochlorite, caustic soda, and proteolytic enzymes.[13] The time required to remove the emulsion depends on the concentration of the chemicals, the temperature, and the amount of agitation. To maintain efficient recovery, the base material must be adequately rinsed. Silver in the form of a sludge is removed from the water by sedimentation or filtration.

The average user of photographic products will find it hard to justify the purchase of equipment designed to recover silver with the processes described above. "Because these processes require specialized equipment, it is generally more efficient for the printer to sell the scrap and let the refiner do the work."[14] There are a large number of reclaimers, refiners, and smelters that offer to purchase scrap film and paper that no longer have any photographic value. A list of many of these firms is offered in Appendix E.

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13 "Recovering Silver," p. 11.

14 "How Much Profit Are You Flushing Down the Drain?," Graphic Arts Monthly, Vol. 41 (November 1969), p. 45.

Methods of Recovery from Photographic Processing Solutions

There are three basic methods of recovering silver from used photographic processing solutions: metallic replacement, electrolytic plating, and chemical precipitation. Any of these three methods can be used separately or in combination, depending on which is most suitable for the particular needs of the user. By far, the most commonly used methods are metallic replacement and electrolytic plating. This is probably due to the fact that the precipitation method is a long process and requires several holding or storage tanks and special filtration. At this time, each of these three methods should be examined in detail. Before going further in this examination, it should be noted that a glossary of silver recovery related terms appears in Appendix F.

Metallic Replacement

Metallic replacement occurs when a metal such as iron or zinc comes in contact with a solution containing dissolved silver ions. A chemical reaction takes place that causes the iron or zinc to go into the solution as an ion while the silver ion becomes metal in the form of a sludge. For the sake of convenience and economy, most of these systems use steel wool.

The acidity of the fix is an important factor when using steel wool in the recovery of silver. Iron will

dissolve in acid solutions, and once the iron is dissolved, it will no longer react with silver ions. Therefore, too strong an acid solution will result in the loss of some of the steel wool. However, some dissolution of the iron by the acid fix is desirable because the etching action of the acid exposes new surface area to the solution. Excess alkalinity slows the replacement reaction. According to Kodak, "Most fixes are within the range of pH (a measure of acidity) for good utilization of steel wool. Below a pH of 4, the dissolution of the steel wool is too rapid. Above a pH of 6, the replacement reaction is so slow that an excessive amount of silver may be lost due to the long reaction time required to recover the silver."[15]

In most replacement systems, hypo is poured into or passed through a cartridge containing steel wool. When the cartridge has collected all the silver it can hold, it is packed and shipped to a refiner. After removal of the silver by metallic replacement, the fixing bath is highly contaminated with iron. Since it has no further photographic use, it must be discarded.

The monitoring of such a system requires no more complex a procedure than to know how much solution passes through the cartridge, at what silver concentration, and

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15 "Recovering Silver," p. 12.

over what period of time. A simple test paper used somewhat as a litmus paper is used, is all that is required to determine if the system is functioning properly. This test paper is usually supplied by the manufacturer.

Electrolytic Plating

In the electrolytic plating process, the silver is removed by passing a controlled direct electric current between two electrodes (an anode and a cathode) which are hung in the fixing solution. Silver is deposited on the cathode in the form of nearly pure silver plate. The cathodes are removed periodically and the silver is removed.[16]

During the recovery process, competing reactions occur at the cathode. If the current is too strong for the amount of silver present in the solution, the thiosulphate in the fixer will decompose, forming sulfide. This "Sulfiding" problem will reduce the current efficiency and can stop further plating of silver, if serious enough. In systems designed to recirculate the fix, the formation of sulfide may make the fixer unfit for reuse. When the current is too strong there will usually be a warning sign; the silver plating on the cathode will become dark brown or black, rather than being the usual cream or light-brown

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16 Anonymous, "The Argenta Series-Silver Recovery Systems," (Los Gatos, California: Future Systems, Inc., 1971), p. 16.

color. The proper current strength to use in plating depends on many factors. The type of fixer being used is important. Ammonium thiosulphate solutions will withstand the strongest current. As a result, silver is collected on the cathode much faster than with a sodium thiosulphate solution. For the same reason, lower current levels can be tolerated with ammonium thiosulphate solutions without sulfiding. Silver is plated much more efficiently in an acid fixing solution than in an alkaline fixer. Kodak has determined the optimum pH or acidity of the fix to be about 4.5. Fixers with a higher pH can be desilvered, but a lower current usually must be used.

Another factor to consider when determining proper current strength is the extent to which the fixing solution is agitated. A system designed to agitate or recirculate the fixer is generally required to furnish a continuous supply of silver-laden fixer around the cathode. If the fixer is not agitated, the current will be too strong for the amount of silver concentrated in the solution near the cathode and will result in the formation of sulfide. The greater the current strength, the greater the amount of agitation required to maintain efficient plating at a given silver concentration.

The concentration of silver in the fixing bath also affects proper current strength. The higher the silver content, the more silver ions that will be present around

the cathode. Batch-type (non-agitating) electrolytic systems can be operated at higher currents at the start of the recovery process, but later the current must be reduced as the silver is removed. Systems which recirculate fixer can be operated continuously without varying the current strength.

It should be noted that dirt in the fixing bath can also affect plating. Accumulated dirt in a fixing solution can be troublesome since it may plate or be retained in the silver plate. Dirt particles can become areas of preferential plating and result in large lumps on the cathode. This condition leads to sulfiding of the bath and can eventually short-out the cell. For this reason, good filtration of the used fixing solution prior to recovery is necessary in systems where the fixer is to be reused.

Electrolytic recovery systems can be installed in two basic ways. One is to desilver the fixer overflow from a processing machine as it flows to a sewer drain. This system can be operated for either a batch or continuous flow-through cell. Another method is to remove silver from the fixer in a continuously recirculating system at approximately the rate at which it is being added by processing. The latter has the advantage of maintaining a low silver concentration in the processing bath so that the amount of silver carried out with the fixer into the wash tanks is minimal. A modification of the circulating system is to

collect fixer overflowing from several processing machines, desilver it in a separate electrolytic system, and then reconstitute the desilvered fixer to supply the processing equipment again.

There are many different sizes of electrolytic systems, each varying in cost of operation and installation. The smallest recovery systems are designed for use inside the fixing tanks of the processing equipment, with the power supply mounted nearby. With this type of system the installation cost is relatively low, however, with larger units or installations on mechanized processing equipment, it is necessary to mount the entire unit outside the fixing tank to allow processing without interference from the unit. With these larger systems, installation costs are higher because of plumbing, mounting, separate tanks, and other necessary equipment which must be included in the installation.

The labor required to operate these systems varies with the size and type of installation. Units that are operated on overflow from the fixing bath where the desilvered solution is discarded require little attention to regulate the chemistry, but should be frequently checked to insure that proper silver recovery efficiency is being maintained. Units operating in a recirculating system require more attention because of possible interaction with the chemicals of the fixing bath. In larger installations,

this additional attention is justified because a higher percentage of silver can be recovered in a recirculation system than in an overflow system. This is because the silver content in the processor fixer tank is maintained at a lower level, therefore reducing the amount of silver lost by carry-out on the film or paper.

Whether the unit is used in the fixer tank or in a circulation system, chemical control of the solution is necessary, and the operation of the units must be balanced to the processing load. Both the large and small types of units must be dismantled and cleaned at regular intervals, and the silver collected and shipped to the refiner.

As mentioned earlier, metallic replacement and electrolytic plating are the two most widely used methods of recovering silver from photographic processing solutions. However, to make this study complete, the chemical precipitation process should also be described.

Chemical Precipitation

In this process, compounds are added to spent fixing baths to precipitate the silver contained in them. These compounds cause the silver to precipitate in the form of a sludge on the bottom of the tank used for recovery. The solution floating above the sludge is decanted off and the sludge is then filtered, dried, and packaged for shipment to a refiner. Because of the fine colloidal nature of

precipitated silver, filtration is usually a slow process. Fixing baths desilvered in this manner must be discarded because they are no longer suitable for photographic use.

There are two basic methods used to chemically precipitate silver from fixing solutions. One of these methods is the sulfide recovery method in which sodium sulfide is used to precipitate the silver. Another method is the ion-exchange method in which ion-exchange resins are used to precipitate the silver. This method is considered too expensive because the resins have a limited capacity and the problem of recovering the silver from the resins also exists.

In addition to metallic replacement, electrolytic plating and chemical precipitation, other methods of recovery have been tried in the past with varying success. "Many more chemical agents besides sodium sulfide will precipitate silver from fixes; sodium hydrosulfite and sodium borohydride are but two. However, sodium sulfide is one of the cheapest and most readily available of the chemicals that successfully precipitate silver."[17]

Substantial quantities of silver are lost in the wash process following the fix. Ion-exchange and reverse osmosis are being investigated as possible techniques for recovering silver from these extremely dilute solutions.

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17 "Recovering Silver," p. 22.

Choosing a Method of Recovering Silver From Photographic Processing Solutions

In general, those firms engaged in processing photographic films, plates, and papers can use two different approaches to silver recovery. They, themselves, can recover silver in their plant by any of the methods just described, or they can contract for the services of firms who specialize in this field. The choice depends on the firm's available personnel who can be used to operate and maintain the recovery system at a lower cost than would be incurred if a services company were used.

One might also want to consider the services rendered by service organizations in addition to silver recovery. These organizations offer various types of services. Some services offer a pick-up service for exhausted fixing baths, while others participate in a solution-exchange program. Some services also set up, maintain, and service a complete silver recovery service custom designed for the user's needs. For those firms that use the metallic replacement process, there are "proprietary systems" in which the smelter or refiner loans or rents silver-reclaiming filters or silver-collector plates to the user. When these are filled with silver, the refiner takes them back and pays the user for the increase in weight attributable to silver. Some silver reclaiming services furnish, install, and maintain the silver recovery equipment at no cost. These services

refine the silver and then pay the user 50 per cent of the gross dollar value of the silver.

If the user decides to recover silver in his own plant, he should choose between electrolytic recovery and metallic replacement recovery. Chemical precipitation processes are seldom used because of the simplicity and ease of alternate methods. Each of the three processes has its advantages and disadvantages. The potential buyer of silver recovery equipment should be aware of these in order to help himself decide which process best suits his needs. Therefore, the following pages list the advantages and disadvantages of each process. Kodak lists these as follows:[18]

Electrolytic Recovery

Advantages:

1. Economical in cost per ounce of silver recovered in large scale operations.

2. Permits the reuse of, or increases the life of, sodium thiosulphate fixing baths. This advantage may not be realized with ammonium thiosulphate fixers.

3. When incorporated with a continuous circulating system, more silver is available for recovery. More efficient washing is realized because less silver is carried over into the following wash.

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18 "Recovering Silver," pp. 22-24.

4. The process is considered to be clean and yields silver of a high degree of purity. As a result, shipping costs to the refiner are kept at a minimum. The dry silver plate normally will assay between 92 and 98 per cent silver. The plate can be easily dried before shipping.

Disadvantages:

1. Electrolytic equipment is relatively high priced.

2. Requires frequent monitoring to insure proper operation.

3. Recovery efficiency may not be as high as metallic replacement systems unless the system is well monitored and controlled.

4. Requires time to strip the silver from the cathode. The stripped silver flake must be handled with the security appropriate for valuable materials.

5. May create a space problem in crowded processing areas.

Metallic Replacement Recovery

Advantages:

1. When used as directed, the system will remove up to 99 per cent of the available silver from the fixer passing through the equipment.

2. Necessary equipment is inexpensive.

3. Simple, nonelectrical installation.

4. Requires little attention. The metal cartridge

is easily replaced when exhausted and the silver is removed. This is conveniently done by replacing the spent cartridge with a fresh one.

5. System is readily adaptable to either manual or mechanized processing operations.

Disadvantages:

1. Fixing bath, after recovery, has no further photographic use.

2. Does not lower silver concentration of working fixing bath.

Chemical Precipitation Recovery

Advantages:

1. 100 per cent of dissolved silver is precipitated.

2. Very economical; equipment consists primarily of inexpensive holding tanks.

3. Requires a minimum of skill or manual dexterity.

4. Simple nonelectrical system.

Disadvantages:

1. Settling times are very long. This requires holding tanks of a size commensurate with several days' output of fixer. Not particularly suited for very large installations.

2. Removal of particulate solids from the desilvered fix is a problem. Decantation is slow and filtration requires an expenditure for equipment.

3. Requires the storage of chemicals which can potentially contaminate the photographic process.

4. Desilvered fixing bath is usually unsuitable for reuse in photographic processes.

Selling the Recovered Silver

Once an organization installs a silver recovery system, it must find a buyer for its reclaimed silver. There are smelters, reclaimers, and refiners that are interested in purchasing this silver. These potential buyers can be found in local classified telephone directories or in the Thomas Register of American Manufacturers, which is available in most of the larger libraries.

Many of these firms will buy any kind of silver waste from the photographic process, such as scrap film and paper, sludges, silver plate or flake, and exhausted metallic replacement cartridges. Some of these companies offer truck pick-up service in large cities, or supply containers for shipping from other areas. The assay, refining, and handling charges vary according to the amount of waste involved and the degree of purity.

Appendix E presents a listing of silver services, reclaimers, collectors, refiners, and manufacturers of silver recovery equipment that purchase reclaimed silver in different forms. This listing was drawn from two sources. The majority of the listings were supplied by the Eastman

Kodak Company. Kodak's listings are supplemented with the names of firms whose responses to the mail questionnaire indicated that they purchased reclaimed silver.

While the listings would appear to be quite comprehensive, they are by no means complete. Kodak recommends: "It may be advisable for the individual looking for silver recovery services to contact several of these people (or others that may not be listed) to determine which firm or firms can best satisfy his needs."[19]

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19 "Recovering Silver," p. 24.

CHAPTER IV

COMPARATIVE CLASSIFICATION OF SILVER RECOVERY EQUIPMENT FOR THE GRAPHIC ARTS INDUSTRY

This chapter is composed of six tables. Each table contains pertinent data regarding the characteristics of 31 models of silver recovery devices manufactured by 11 different companies. As noted in chapter 2, the material presented in this chapter came from completed questionnaires, reports, papers and pamphlets received from suppliers of silver recovery equipment. The author wishes to note that although 18 suppliers responded to the mail survey, only 11 are included in this chapter. Only 11 firms are presented, because the other respondents either supplied the same equipment or were no longer suppliers. The first two columns of Tables 5 through 9 list suppliers and the silver recovery devices available from each supplier. Where column headings in the tables do not pertain to a particular model of silver recovery device, "Does not apply" is noted in the appropriate space. If specific information regarding a piece of silver recovery equipment was unavailable from the supplier, "Not available" appears in the appropriate space.

Table 4 lists the names and addresses of those suppliers whose equipment is compared in this chapter, so that

the reader may contact the supplier for further information if he desires. This table also indicates whether the supplier is the manufacturer of the equipment, a distributor only, or a combination of both. Those manufacturers whose equipment is also distributed by other firms are indicated by an asterisk.

Table 5 notes which of the silver recovery processes is employed by each model of silver recovery device. Also listed in this table is the recovery efficiency of each model. The efficiency of a silver recovery device may be thought of in two ways; the system efficiency and the chemical or electrochemical efficiency. The system efficiency refers to the percentage of the total available silver that is recovered by the system. The chemical or electrochemical efficiency is the efficiency at which the actual reaction of recovery proceeds.

The recovery efficiencies listed in Table 5 refer to the system efficiency of each device. The goal of any silver recovery system is to recover as much silver as possible, as economically as possible. The value of electricity or steel wool is generally insignificant, compared to the value of the silver recovered. Therefore, the only important consideration is the system efficiency, or how much of the available silver is actually being recovered.

Table 6 presents the recovery capacity of each model of silver recovery device and the assay value of the silver

recovered by each device. The recovery capacity refers to the maximum number of Troy ounces of silver that can be recovered by a device in one hour of continuous operation. The assay value of the recovered silver refers to the purity of the silver.

Table 7 indicates the method or methods in which each piece of silver recovery equipment can be installed to recover silver. A processor overflow installation removes silver from the fixer overflow streams of automatically replenished processing equipment. With the tandem hookup type of installation, two silver recovery devices are used in series in order to handle a large amount of fixing solution.

Batch recovery refers to installations where exhausted fixing solution is saved from tray or tank changes and is then processed for silver recovery when enough fixer is accumulated. This type of installation is generally used when a firm does its film and paper processing in trays, using small batches of fixing solution. Firms using film or paper processing equipment generally use a fixer recirculation system in which silver is continuously removed, and the fixer is pumped back into the processing equipment for reuse.

Table 8 indicates the labor and power requirements for each model of silver recovery device. Labor requirements refer to the the amount of labor needed to operate the equipment, and are presented in three forms; operates unattended, must be attended, and needs periodic observation.

Power requirements are included because the cost of rewiring for new equipment can be substantial.

Table 9 presents the rental and/or purchase price for each piece of silver recovery equipment. These include the acquisition cost of the equipment only. Where installation of the equipment has to be done by the manufacturer or distributor, there are usually additional charges.

TABLE 4

A COMPARATIVE CLASSIFICATION OF SUPPLIERS
AND NATURE OF BUSINESS

Supplier	Nature of Business
Arriflex Corporation of America 25-20 Brooklyn Queens Expressway West New York, New York 10010	Distributor only
CinTel Corporation 11801 W. Olympic Blvd. Los Angeles, California 90064	Manufacturer and distributor
Eastman Kodak Company 343 State Street Rochester, New York 14650	*Manufacturer and distributor
Fairchild Hiller Space & Electronics Sherman Fairchild Technology Center Fairchild Drive Germantown, Maryland 20767	Manufacturer and distributor
Oscar Fisher Company, Inc. P.O. Box 426 Newburgh, New York 12553	Manufacturer and distributor
Future Systems, Inc. 809 University Avenue P.O. Box 1820 Los Gatos, California	Manufacturer and distributor
Motion Picture Equipment Co., Inc. 6430 Central Avenue Seat Pleasant, Maryland 20027	*Manufacturer and distributor

TABLE 4 (continued)

Supplier	Nature of Business
Silvermat Service Company 9300 Manchester Road St. Louis, Missouri 63119	Distributor only
W.B. Snook Corporation Rotex Division 751 Loma Verde Avenue Palo Alto, California 94303	*Manufacturer and distributor
States Smelting and Refining Corporation 1550 Elida Road Lima, Ohio 45805	Manufacturer and distributor
X-Rite Company 4500 Roger Chaffee Dr., S.E. Grand Rapids, Michigan 49508	*Manufacturer and distributor

* Write manufacturer for name and address of local distributor.

TABLE 5

A COMPARATIVE CLASSIFICATION OF RECOVERY PROCESSES AND RECOVERY EFFICIENCY FOR EACH MODEL OF SILVER RECOVERY DEVICE

Supplier	Model	Process Employed	Recovery Efficiency
Arriflex Corp. of America	10A	Electrolytic plating	Up to 100%
	25A	Electrolytic plating	Up to 100%
	50A	Electrolytic plating	Up to 100%
	100A	Electrolytic plating	Up to 100%
CinTel Corp.	Mini-Agtec Model 50	Electrolytic plating	Up to 95%
	Midi-Agtec Model 240	Electrolytic plating	Up to 95%
	Maxi-Agtec Model 600	Electrolytic plating	Up to 95%
Eastman Kodak Company	Recovery Cartridges Types 1P & 2P	Metallic replacement	95 to 99%
Fairchild Hiller Corporation	1150	Destruction of film by burning	98 to 100%

TABLE 5 (continued)

Supplier	Model	Process Employed	Recovery Efficiency
Oscar Fisher Company, Inc.	Ag-Omat	Electrolytic plating	98%
Future Systems, Inc.	Argenta Model 5	Electrolytic plating	Not available
	Argenta Model 10	Electrolytic plating	Not available
	Argenta Model 30	Electrolytic plating	Not available
	Argenta Model 60	Electrolytic plating	Not available
	Argenta Model 75	Electrolytic plating	Not available
Motion Picture Equipment Co.	Sterling 1	Electrolytic plating	95 to 98%
	Sterling 2	Electrolytic plating	95 to 98%
	Sterling 3	Electrolytic plating	95 to 98%
	Sterling 10	Electrolytic plating	95 to 98%
Silvermat Service Company	Silvermat Processor	Metallic Replacement	100%

TABLE 5 (continued)

Supplier	Model	Process Employed	Recovery Efficiency
W.B. Snook Corp. Rotex Division	Ag-Get	Electrolytic plating	97 to 98%
	X-4	Electrolytic plating	97 to 98%
	500-2	Electrolytic plating	97 to 98%
	234	Electrolytic plating	97 to 98%
	1033	Electrolytic plating	97 to 98%
	1060	Electrolytic plating	97 to 98%
	2000	Electrolytic plating	97 to 98%
States Smelting & Refining Corp.	Tam-o-flo	Electrolytic plating	90 to 100%
X-Rite Company	Prospector Model 15	Electrolytic plating	95+%
	Prospector Model 100	Electrolytic plating	95+%
	Prospector Model 300	Electrolytic plating	95+%

TABLE 6

A COMPARATIVE CLASSIFICATION OF RECOVERY CAPACITY AND ASSAY VALUE OF SILVER RECOVERED WITH EACH MODEL OF SILVER RECOVERY DEVICE

Supplier	Model	Recovery Capacity (Troy ounces/hr.)	Assay Value (% pure silver)
Arriflex Corp. of America	10A	.8	Not available
	25A	2.0	Not available
	50A	4.0	Not available
	100A	8.0	Not available
CinTel Corp.	Mini-Agtec Model 50	.7	97 to 99+ %
	Midi-Agtec Model 240	3.0	97 to 99+ %
	Maxi-Agtec Model 600	7.5	97 to 99+ %
Eastman Kodak Company	Recovery Cartridges Types 1P & 2P	Not available	Not available
Fairchild Hiller Corporation	1150	Does not apply	99+ %

TABLE 6 (continued)

Supplier	Model	Recovery Capacity (Troy ounces/hr.)	Assay Value (% pure silver)
Oscar Fisher Company, Inc.	Ag-Omat	2.0	98+ %
Future Systems, Inc.	Argenta Model 5	.5	98 to 99%
	Argenta Model 10	1.25	98 to 99%
	Argenta Model 30	3.0	98 to 99%
	Argenta Model 60	7.5	98 to 99%
	Argenta Model 75	9.0	98 to 99%
Motion Picture Equipment Co.	Sterling 1	1.0	99.7%
	Sterling 2	2.0	99.7%
	Sterling 3	3.0	99.7%
	Sterling 10	10.0	99.7%
Silvermat Service Company	Silvermat Processor	Unlimited	33%

TABLE 6 (continued)

Supplier	Model	Recovery Capacity (Troy ounces/hr.)	Assay Value (% pure silver)
W.B. Snook Corp. Rotex Division	Ag-Get	1.0	95 to 96%
	X-4	1.5	95 to 96%
	500-2	1.5	95 to 96%
	234	2.0	95 to 96%
	1033	3.0+	95 to 96%
	1060	3.0+	95 to 96%
	2000	13.0	95 to 96%
States Smelting & Refining Corp.	Tam-o-flo	50 oz. per cleaning	95 to 98%
X-Rite Company	Prospector Model 15	.15	90 to 97%
	Prospector Model 100	1.0	90 to 97%
	Prospector Model 300	3.0	90 to 97%

TABLE 7

A COMPARATIVE CLASSIFICATION OF METHODS IN WHICH EACH MODEL OF SILVER RECOVERY DEVICE CAN BE INSTALLED

Supplier	Model	Methods of Installation
Arriflex Corp. of America	10A	Tandem hookup Batch recovery Recirculation system
	25A	Tandem hookup Batch recovery Recirculation system
	50A	Tandem hookup Batch recovery Recirculation system
	100A	Tandem hookup Batch recovery Recirculation system
CinTel Corp.	Mini-Agtec Model 50	Processor overflow Tandem hookup Batch recovery Recirculation system
	Midi-Agtec Model 240	Processor overflow Tandem hookup Batch recovery Recirculation system
	Maxi-Agtec Model 600	Processor overflow Tandem hookup Batch recovery Recirculation

TABLE 7 (continued)

Supplier	Model	Methods of Installation
Eastman Kodak Company	Recovery Cartridges Types 1P & 2P	Processor overflow Tandem hookup Batch recovery
Fairchild Hiller Corporation	1150	Does not apply
Oscar Fisher Company, Inc.	Ag-Omat	Processor overflow Tandem hookup Batch recovery Recirculation system
Future Systems, Inc.	Argenta Model 5	Processor overflow Tandem hookup Batch recovery Recirculation system
	Argenta Model 10	Processor overflow Tandem hookup Batch recovery Recirculation system
	Argenta Model 30	Processor overflow Tandem hookup Batch recovery Recirculation system
	Argenta Model 60	Processor overflow Tandem hookup Batch recovery Recirculation system
	Argenta Model 75	Processor overflow Tandem hookup Batch recovery Recirculation system

TABLE 7 (continued)

Supplier	Model	Methods of Installation
Motion Picture Equipment Co.	Sterling 1	Processor overflow Tandem hookup Batch recovery Recirculation system
	Sterling 2	Processor overflow Tandem hookup Batch recovery Recirculation system
	Sterling 3	Processor overflow Tandem hookup Batch recovery Recirculation system
	Sterling 10	Processor overflow Tandem hookup Batch recovery Recirculation system
Silvermat Service Company	Silvermat Processor	Processor overflow
W.B. Snook Corp. Rotex Division	Ag-Get	Processor overflow Tandem hookup Batch recovery
	X-4	Batch recovery
	500-2	Processor overflow
	234	Processor overflow Recirculation system

TABLE 7 (continued)

Supplier	Model	Methods of Installation
W.B. Snook Corp. Rotex Division (continued)	1033	Processor overflow Batch recovery Recirculation system
	1060	Processor overflow Batch recovery Recirculation system
	2000	Not available
States Smelting & Refining Corp.	Tam-o-flo	Processor overflow Tandem hookup Batch recovery Recirculation system
X-Rite Company	Prospector Model 15	Batch recovery Recirculation system
	Prospector Model 100	Processor overflow Tandem hookup Batch recovery Recirculation system
	Prospector Model 300	Processor overflow Tandem hookup Batch recovery Recirculation

TABLE 8

A COMPARATIVE CLASSIFICATION OF LABOR AND POWER REQUIREMENTS FOR EACH MODEL OF SILVER RECOVERY DEVICE

Supplier	Model	Labor Required	Power Required
Arriflex Corp. of America	10A	Operates unattended	220V A.C.
	25A	Operates unattended	220V A.C.
	50A	Operates unattended	220V A.C.
	100A	Operates unattended	220V A.C.
CinTel Corp.	Mini-Agtec Model 50	Needs periodic observation	115V A.C.
	Midi-Agtec Model 240	Operates unattended	115V A.C.
	Maxi-Agtec Model 600	Operates unattended	115V A.C.
Eastman Kodak Company	Recovery Cartridges Types 1P & 2P	Needs periodic observation	None required
Fairchild Hiller Corporation	1150	Needs periodic observation	115V A.C.

TABLE 8 (continued)

Supplier	Model	Labor Required	Power Required
Oscar Fisher Company, Inc.	Ag-Omat	Operates unattended	115V A.C.
Future Systems, Inc.	Argenta Model 5	Operates unattended	115V A.C.
	Argenta Model 10	Operates unattended	115V A.C.
	Argenta Model 30	Operates unattended	115V A.C.
	Argenta Model 60	Operates unattended	115V A.C.
	Argenta Model 75	Operates unattended	115V A.C.
Motion Picture Equipment Co.	Sterling 1	Needs periodic observation	115V A.C.
	Sterling 2	Needs periodic observation	115V A.C.
	Sterling 3	Needs periodic observation	115V A.C.
	Sterling 10	Needs periodic observation	115V A.C.
Silvermat Service Company	Silvermat Processor	Operates unattended	115V A.C.

TABLE 8 (continued)

Supplier	Model	Labor Required	Power Required
W.B. Snook Corp. Rotex Division	Ag-Get	Needs periodic observation	115V A.C.
	X-4	Operates unattended	115V A.C.
	500-2	Needs periodic observation	115V A.C.
	234	Operates unattended	115V A.C.
	1033	Operates unattended	115V A.C.
	1060	Operates unattended	115V A.C.
	2000	Not available	115V A.C.
States Smelting & Refining Corp.	Tam-o-flo	Operates unattended	115V A.C.
X-Rite Company	Prospector Model 15	Needs periodic observation	115V A.C.
	Prospector Model 100	Operates unattended	115V A.C.
	Prospector Model 300	Operates unattended	115V A.C.

TABLE 9

A COMPARATIVE CLASSIFICATION OF THE RENTAL AND/OR PURCHASE PRICE FOR EACH SILVER RECOVERY DEVICE

Supplier	Model	Monthly Rental	Purchase Price
Arriflex Corp. of America	10A	Does not apply	$2,960
	25A	Does not apply	$3,730
	50A	Does not apply	$4,300
	100A	Does not apply	$4,980
CinTel Corp.	Mini-Agtec Model 50	Does not apply	$229
	Midi-Agtec Model 240	Does not apply	$675
	Maxi-Agtec Model 600	Does not apply	$2,295
Eastman Kodak Company	Recovery Cartridges Types 1P & 2P	Does not apply	$16
Fairchild Hiller Corporation	1150	Not available	$13,250

TABLE 9 (continued)

Supplier	Model	Monthly Rental	Purchase Price
Oscar Fisher Company, Inc.	Ag-Omat	Does not apply	$750
Future Systems, Inc.	Argenta Model 5	Does not apply	$255
	Argenta Model 10	Does not apply	$495
	Argenta Model 30	Does not apply	$795
	Argenta Model 60	Does not apply	$2,950
	Argenta Model 75	Does not apply	$3,895
Motion Picture Equipment Co.	Sterling 1	Does not apply	$1,195
	Sterling 2	Does not apply	$1,550
	Sterling 3	Does not apply	$2,595
	Sterling 10	Does not apply	$6,500
Silvermat Service Company	Silvermat Processor	50% of silver recovered "proprietary system"	Does not apply

TABLE 9 (continued)

Supplier	Model	Monthly Rental	Purchase Price
W.B. Snook Corp. Rotex Division	Ag-Get	Does not apply	$299
	X-4	Does not apply	$595
	500-2	Does not apply	$887
	234	Does not apply	$1,130
	1033	Does not apply	$1,795
	1060	Does not apply	$2,010
	2000	Does not apply	$6,000
States Smelting & Refining Corp.	Tam-o-flo	$39.00 Deposit plus 50% of silver recovered "proprietary system"	(or) $295
X-Rite Company	Prospector Model 15	Does not apply	$160
	Prospector Model 100	Does not apply	$320
	Prospector Model 300	Does not apply	$1,395

CHAPTER V

CONCLUSION

Why recover silver from photographic products? Why not let it just go down the drain in used photograhic fixer, or throw it away in used film and paper? The answer is found in three major problems now facing the graphic arts industry. Simply stated, the graphic arts industry faces: (1) a severe shortage of silver, an essential raw material in the manufacturing of photographic supplies; (2) rising production costs due to the ever increasing cost of photographic supplies, and (3) government regulation of disposal of photographic wastes due to public concern about water pollution.

Within the last two years, the graphic arts industry has become increasingly aware that silver recovery can be an effective means for solving these problems. Those firms that have already begun using silver recovery equipment have found that they are able to: reduce operation costs; increase the quantity of available silver; minimize rising costs of photographic supplies; insure a steady availability of such supplies, and do their part in pollution abatement.

Only through information supplied by firms doing research for the graphic arts industry or studies such as

this, can those in the graphic arts industry be made aware of the advantages of silver recovery. In every new issue of publications dealing with the graphic arts industry, more and more manufacturers of silver recovery equipment offer free information about silver recovery.

Although manufacturers are informing the graphic arts industry about the importance of silver recovery, most of them only offer information about the equipment they themselves manufacture, which is to be expected. Therefore a study of this type, which includes data on many different brands and models of silver recovery devices has more to offer the potential buyer of silver recovery equipment.

Firms considering the recovery of silver in their own plant have a variety of alternatives open to them. By contracting for a "proprietary system," a firm can start recovering silver without any outlay of capital, or it can purchase its own equipment for as little as $160. The type and cost of equipment purchased, will depend largely on the volume of recoverable silver the firm wishes to reclaim. For reasons described earlier, the most widely used types of equipment are those that use the electrolytic plating and metallic replacement processes.

Available types of silver recovery equipment recover from 90 to 100 per cent of the silver potentially recoverable from used photographic materials, with the silver

assaying from a range of 90 to 99 per cent pure silver. Most models can be installed to recover silver in more than one way, and are designed to recover from as little as .15 Troy ounces of silver per hour or as much as 13 Troy ounces of silver per hour of continuous operation.

The majority of silver recovery devices operate on regular 115 Volt A. C. power and require no rewiring during installation. Most silver recovery equipment operates unattended, or needs only periodic observation during operation.

Considering the described problems now facing the graphic arts industry and the relative ease with which these problems can be solved through silver recovery, the author foresees a great increase in the number of graphic arts firms installing silver recovery equipment.

APPENDIX A

EXAMPLE OF LETTER OF INQUIRY

Dear Sir:

Your article on silver recovery which appeared in the August 1970 issue of Printing Production has inspired me to further investigate silver recovery, but I could use some help.

I am studying for my Master's Degree in Printing Management at South Dakota State University. Currently, I am doing research for a master's thesis concerning silver recovery for the Graphic Arts.

By writing people that are knowledgeable in this field, I hope to answer questions such as:

a) Why is the salvage of silver important?

b) What processes are now available for silver recovery?

c) What are the advantages and disadvantages of the different processes?

d) Who sells or leases equipment for the reclaiming of silver?

e) What is the cost of the equipment or service?

f) To what extent is the Graphic Arts Industry using this equipment?

g) How would a firm evaluate its potential savings from silver recovery?

Would you please send me any technical bulletins, brochures, photographs or literature that could help me answer these questions? It is my belief that this type of study can be of much value to our industry. Your time and assistance in making this study complete is greatly appreciated.

Sincerely yours,

Kenneth K. Bittner

APPENDIX B

EXAMPLE OF REPLIES RECEIVED FROM PERSONS WHO WERE SENT A LETTER OF INQUIRY

EASTMAN KODAK COMPANY

ROCHESTER, NEW YORK 14650

ADDRESS REPLY TO
PARK WORKS

TELEPHONE
AREA CODE 716 GLADSTONE 8-1000

February 1, 1971

Mr. Kenneth K. Bittner
Scobey Hall, Room 468
University Station
Brookings, South Dakota 57006

Dear Mr. Bittner:

Attached are copies of Kodak Publications No. J-9, "Silver Recovery with the Kodak Chemical Recovery Cartridge," No. J-10, "Recovering Silver from Photographic Materials," and No. J-32, "Recovery of Silver from Discarded Photographic Films and Papers". These contain the answers to the questions asked in your recent letter. The Eastman Kodak Company, as well as other manufacturers of photographic products and users of silver, have been concerned for some time about conserving this important natural resource. The Graphic Arts industry is a significant and rapidly growing user of photographic goods and a study such as you are undertaking should be a valuable contribution in the area of silver recovery.

Your very truly,

Richard H. Forbes

Richard H. Forbes
Coordinator for Silver Recovery

RHForbes:PAM
Enclosures

APPENDIX C

EXAMPLE OF QUESTIONNAIRE MAILED TO MANUFACTURERS AND DISTRIBUTORS OF SILVER RECOVERY EQUIPMENT

Please answer the following questions by checking or providing the appropriate answer in the spaces provided.

Company name_____

(1) Which of the following categories best describes your organization?

_____ manufacturer of silver recovery equipment
_____ distributor only
_____ both a manufacturer and distributor

(2) Which of the following best describes your firm's distribution of silver recovery equipment?

_____ sells (only)
_____ rents (only)
_____ rents and sells equipment

(3) If your organization sells and rents silver recovery equipment, approximately what percentage of your business is: (indicate 0-100%)

_____ on a purchase basis _____ on a rental basis

(4) Please list the silver recovery equipment or machines your organization presently market. (indicate with brandnames and/or model numbers)

1. _____
2. _____
3. _____
4. _____
5. _____

IMPORTANT!

After answering question 4, it is not necessary to re-list the names or models of the silver recovery equipment available from your company. However, when answering all questions after question 4, please be sure that the numbers (1,2,3,4,5) provided with each question correspond with the numbers (1,2, 3,4,5) next to your answers in question 4.

(5) What is the total cost of each piece of silver recovery equipment you listed in question 4?

	Monthly Rental	Purchase Price
1		
2		
3		
4		
5		

(6) What method does each piece of your equipment use to recover silver? (check appropriate box)

	1	2	3	4	5
metallic replacement					
electrolytic plating					
recovery from scrap film					

(7) Please indicate the method or methods in which each type of your equipment can be installed. (indicate more than one method if equipment can be installed in more than one way)

	1	2	3	4	5
processor overflow					
tandem hook-up					
holding tank or batch recovery					
fixer recirculation system					

(8) What is the recovery efficiency of each of your silver recovery devices? (please indicate as a percentage of silver recovered)

1	
2	
3	
4	
5	

(9) What is the assay value of silver recovered by each type of equipment your organization markets? (please indicate as a percentage)

1
2
3
4
5

(10) What is the recovery capacity of each type of equipment you market? (please indicate in Troy ounces/Hr.)

1
2
3
4
5

(11) Which of the following categories best describes your equipment during normal recovery operation?

	1	2	3	4	5
operates unattended					
must be attended					
needs periodic observation					

(12) Indicate how each type of equipment operates.

	1	2	3	4	5
requires electricity					
non-electric					

(13) If electric power is necessary to operate the equipment, please indicate the type of power needed.

	1	2	3	4	5
115V A.C.					
220V A.C.					
440V A.C.					

If other type of power, please list equipment as (1,2,3,4,5) and describe type of power needed_____

_____

(14) Does your organization purchase the recovered silver?

_____ yes _____ no

(15) If you answered yes to question 14, indicate what form of recovered silver your firm purchases. (indicate any number of forms)

_____ metallic cartridges
_____ silver flake
_____ film
_____ paper
_____ ash
_____ solutions
_____ sludge

Any comments you might have will be greatly appreciated.

_____

_____

_____

_____

_____

_____

APPENDIX D

EXAMPLE OF LETTER OF TRANSMITTAL THAT ACCOMPANIED EACH QUESTIONNAIRE MAILED TO MANUFACTURERS AND/OR DISTRIBUTORS OF SILVER RECOVERY EQUIPMENT

Dear Sir:

As a candidate for a Master of Science Degree in Printing Management at South Dakota State University, I am currently involved in a thesis entitled: A Study of Silver Recovery Processes and Comparative Classification of Silver Recovery Equipment for the Graphic Arts Industry.

I realize that your firm manufactures and/or distributes equipment for recovering silver. With this in mind, I would be most appreciative if you could assist me in accumulating data pertinent to my study.

Enclosed with this letter is a questionnaire designed to assist me in obtaining the exact information I need to compile data on silver recovery equipment in a systematic and complete manner. I would be very grateful if you could take some time and fill-in the information I need. If any of the questions cannot be answered because the information is not conveniently at hand, please fill-in those that are convenient to answer. However, a fully completed questionnaire would increase the value and validity of my thesis. If you would rather have another person in your organization complete the questionnaire, please forward it to that individual.

I would appreciate your returning the completed questionnaire in the accompanying self-addressed, stamped envelope at your earliest convenience.

Any further data, information, or literature you believe to be relevant to a study of this type would also be greatly appreciated. I believe that a study of this type can be of value to our industry. Thank you for your time and assistance in making this study possible.

Respectfully yours,

Kenneth K. Bittner

ENCL.

APPENDIX E

A LISTING OF SILVER SERVICES, RECLAIMERS, COLLECTORS, REFINERS AND MANUFACTURERS THAT PURCHASE RECLAIMED SILVER

SILVER SERVICES-NORTHEAST

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Albert Acan X-Ray Solutions 58-09 28th Avenue Woodside, New York 11377	X	X	X	X	X	X	X
American Chemical and Refining Co. P. O. Box 1303 Waterbury, Connecticut 06720			X			X	
American Metal Climax, Inc. 1270 Avenue of the Americas New York, New York 10005			X	X		X	
J. Aron and Company, Inc. 79 Pine St. New York, New York 10020	X	X	X	X	X	X	X
Belmont Smelting & Refining Works 330 Belmont Avenue Brooklyn, New York 11207	(Contact Company)						
Paul Blum Company 315 Larkin Street Buffalo, New York 14210	X						

SILVER SERVICES-NORTHEAST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Midland Processing Inc. 55 Lafayette Avenue North White Plains, New York 10603	X	X	X	X	X	X	X
Ciner Chemical-Refining Co., Inc. 247 Green Street Brooklyn, New York 11222	X	X	X	X	X	X	X
Denzer & Shafer X-Ray Company 95 Pinewood Road Silverton Toms River, New Jersey 08753	X		X		X	X	X
Eastern Smelting & Refining Corp. 37-39 Bubier Street Lynn, Massachusetts 01901	X	X	X	X	X	X	X
Eastman Kodak Company 343 State Street Rochester, N. Y. 14650							X
Engelhard Industries 429 Delancy Street Newark, New Jersey 07105	X	X	X	X	X	X	X

SILVER SERVICES-NORTHEAST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Garfield-Baring Corporation 1215 Cherry Street Philadelphia, Pennsylvania 19107	X	X	X			X	X
General Film Recovery Corp. Caven Point Road Jersey City, New Jersey 07305	X	X					
Gerald Metals, Inc. 25 Broadway New York, New York 10004			X				
Glines and Rhodes West Bacon Street Plainville, Massachusetts 02762			X	X			
W.R. Grace & Company Ore and Mining Division 3 Hanover Square New York, New York 10004	X						
Handy and Harmon 850 Third Avenue New York, New York 10022	X		X	X		X	X

SILVER SERVICES-NORTHEAST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Handy and Harman 1700 Kings Highway Fairfield, Connecticut 06432	X		X	X		X	X
Handy and Harman 845 Waterman Avenue East Providence, Rhode Island 02914	X		X	X		X	X
Howard & Bowen 55 Plover Street Rochester, New York 14613	X	X	X			X	X
Samuel Huberman Metals 299 Broadway New York, New York 10007	X						
Johnson Plastics, Inc. 524-534 Pine Street Elizabeth, New Jersey 07206	X		X			X	X
Long Island Reclaiming Company Film Division 350 Morgan Avenue Brooklyn, New York 11211	X		X			X	

SILVER SERVICES-NORTHEAST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
The Metal Bank of America 6801 State Road Philadelphia, Pennsylvania 19135	X	X	X	X	X	X	X
Newark-Sitkin Steel Warehouse, Inc. 10 Ivy Lane Englewood, New Jersey 17631	X	X	X	X	X	X	X
The J.M. Ney Company Maplewood Avenue Bloomfield, Connecticut 06002			X			X	
Ostrander X-Ray Specialties 1250 MacDade Boulevard Collingdale, Pennsylvania 19023	X		X		X		
Jules Ott, Inc. 497 Scott Avenue Brooklyn, New York 11222	X	X	X	X	X	X	X
M. Pashelinsky & Sons 20 Carbon Place Jersey City, New Jersey 07305	X	X	X	X	X	X	X

SILVER SERVICES-NORTHEAST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Pease & Curren, Inc. 75 Pennsylvania Avenue Warwick, Rhode Island 02888	X	X	X	X	X	X	X
Picker X-Ray Corporation 1275 Mamaroneck Avenue White Plains, New York 10605			X		X	X	X
Pittsburgh X-Ray Chemical Service 7212 Susquehanna Street Pittsburgh, Pennsylvania 15208	X		X		X	X	X
Research Silver Refining Company 903-5 West Baltimore Street Baltimore, Maryland 21223	X	X	X	X	X	X	X
Rochester Smelting & Refining, Inc. 26 Sherer Street Rochester, New York 14611	X	X	X	X			
Sabin Metal Corporation 310-324 Meserole Street Brooklyn, New York 11206	X	X	X	X	X	X	X

SILVER SERVICES-NORTHEAST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
The Safetyloid Company 151 Foundry Street Wakefield, Massachusetts 01808	X						
Sel-Rex Corporation 75 River Road Nutley, Massachusetts 07110	X	X	X	X	X	X	X
Sel-Rex Corporation 105 Bellows Street Warwick, Rhode Island 02888	X	X	X	X	X	X	X
Silver Certification Corp. 400 Spencer Street Syracuse, New York 13204	X	X	X		X	X	X
Sitkin-Greenfield, Inc. P. O. Box 1148 Buffalo, New York 14240	X	X	X	X	X	X	X
Sitkin-Midland, Inc. 13535 Helen Street Detroit, Michigan 48212	X	X	X	X	X	X	X

SILVER SERVICES-NORTHEAST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Sitkin-Smelting & Refining P. O. Box 708 Lewistown, Pennsylvania 17044	X	X	X	X	X	X	X
Spiral Metal Company, Inc. Louisa Street South Amboy, New Jersey 08879	X	X	X	X	X	X	X
Warren X-Ray Company 49 Pleasant Drive Warren, Pennsylvania 16365	X		X				X
X-Ray Darkroom Service 81 Child Street Hyde Park, Massachusetts 02136	X		X	X	X	X	X
York Refining Company 4232 Industrial Place Island Park, New York 11558	X	X	X	X	X	X	X

SILVER SERVICES-MIDWEST

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Acan X-Ray Inc. 919 West 49th Place Chicago, Illinois 60607	X	X	X	X	X	X	X
Albert Acan X-Ray, Inc. 18800 Hawthorne Detroit, Michigan 48233	X	X	X	X	X	X	X
Albert Acan X-Ray, Inc. 2337 Distributors Drive Indianaplis, Indiana 46206	X	X	X	X	X	X	X
Albert Acan X-Ray, Inc. 650 Morris Street Mt. Morris, Michigan 48458	X	X	X	X	X	X	X
Albert Acan X-Ray, Inc. 423 North Ninth Street Niles, Michigan 49120	X	X	X	X	X	X	X
Joseph Behr & Sons, Inc. 1100 Seminary Street Rockford, Illinois 61105	X	X	X	X	X	X	X

SILVER SERVICES-MIDWEST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Cincinnati Gold and Silver Co. 316 West 4th Street Cincinnati, Ohio 45202	X	X	X	X		X	
Denron Refiners, Inc. 1200 West Northbranch Drive Oak Creek, Wisconsin 53154	X	X	X	X	X	X	X
Eastman Kodak Company 343 State Street Rochester, N.Y. 14650							X
General Refineries, Inc. 292-294 Walnut Street St. Paul, Minnesota 55102			X			X	X
Handy & Harman 1900 Estes Avenue Elkgrove Village, Chicago, Ill. 60007	X		X	X		X	X
Landan Rubber and Plastic Products 1308 West Cermak Road Chicago, Illinois 60618	X						

SILVER SERVICES-MIDWEST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Donald McElroy, Inc. Edens Executive Center 3201 Old Glenview Road Wilmette, Illinois 60091	X		X			X	X
Micro X-Ray Recorder, Inc. 3755 West Lawrence Avenue Chicago, Illinois 60625	X						
W.E. Mowrey Company 1435 University Avenue St. Paul, Minnesota 55104		X	X	X	X	X	X
Picker X-Ray Corporation 595 Miner Road Cleveland, Ohio 44143			X		X	X	X
Sel-Rex Corporation 5400 McDermott Drive Berkeley, Illinois 60163	X	X	X	X	X	X	X
Simmons Refining Company 1704 South Normal Avenue Chicago, Illinois 60616	X	X	X			X	X

SILVER SERVICES-MIDWEST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
W.B. Snook Manufacturing Co.,Inc. 7321 Monticello Avenue Skokie, Illinois 60076			X				
States Smelting & Refining Co. 1550 Elida Road Lima, Ohio 45805	X	X	X	X	X	X	X
Harry Thuresson Inc. 7321 Monticello Avenue Skokie, Illinois 60076			X				
United Refining & Smelting Co. 3700-20 North Runge Avenue Franklin Park, Chicago, Illinois 60131	X	X	X	X		X	X

SILVER SERVICES-WEST

A-1 Laboratories 2122 Aaron Street Los Angeles, California 90026	X	X	X	X	X	X	X

SILVER SERVICES-WEST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Film Salvage Company 3602 Crenshaw Boulevard Los Angeles, California 90016	X				X	X	
Future Systems, Inc. 809 University Avenue P.O. Box 1820 Los Gatos, California 95030	X	X	X				
Handy and Harman 4140 Gibson Road El Monte, California 91731	X	X	X	X		X	X
Industrial Silver Company, Inc. 1120 North Citrus Avenue Hollywood, California 90038	X	X	X	X	X	X	X
Kane's Chemicals North 5935 Moore Spokane, Washington 99208	X				X	X	
MacKay Smelting Company, Inc. 1520 Pioneer Road Salt Lake City, Utah 84104	X	X	X	X	X	X	X

SILVER SERVICES-WEST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Martin Metals, Inc. 1321 Wilson St. Los Angeles, California 90021	X	X	X	X	X	X	X
Medical Electronic Service West 522 Cataldo Avenue Spokane, Washington 99201	X						
Merry X-Ray Chemical Corp. 1476 Island Avenue San Diego, California 92101	X	X	X	X	X	X	X
Micro-Security Company 5303 Irving Street P.O. Box 7883 Boise, Idaho 83707	X	X	X	X	X	X	X
Noble Metals 4703 Maple Spokane, Washington 99208	X	X	X	X	X	X	X
Sel-Rex Corporation 20801 Nordhoff Street Chatsworth, California 91311	X	X	X	X	X	X	X

SILVER SERVICES-WEST (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
W.B. Snook Manufacturing Co., Inc. 751 Loma Verde Avenue Palo Alto, California 94303			X				
Southland X-Ray Company 1130 North Citrus Street Orange, California 92666	X	X	X	X	X	X	X
Urell, Inc. 2630 Humboldt Street Los Angeles, California 90031	X		X		X		X
R.E. van Valey, Inc. 1317 Republican Street Seattle, Washington 98109	X	X	X	X	X	X	X
Wildberg Bros. Smelting & Refining 349 Oyster Point Boulevard P.O. Box 2207 South San Francisco, California 94080			X	X		X	X
X-Ray Film Processing Company 1820 Fourth Street Berkeley, California 94710	X	X	X	X	X	X	X

SILVER SERVICES-SOUTH

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Distasio X-Ray Company P.O. Box 11106 St. Petersburg, Florida 33733	X		X		X		
Eastman Kodak Company 343 State Street Rochester, N. Y. 14650							X
Film Salvage Company 211 College Street Mountain City, Tennessee 37683	X				X	X	
Houston Electro-Chemical Refining 700 Nueces Houston, Texas 77012	X	X	X	X	X	X	X
International Recovery Company Box 33187 Houston, Texas 77033	X	X	X	X	X	X	X
Merry X-Ray Corporation 1617 East Jefferson Street Phoenix, Arizona 85034	X	X	X	X	X	X	X

SILVER SERVICES-SOUTH (CONT'D)

Company	Film	Paper	Electrolytic Silver (Flake)	Ash	Solutions	Sludge	Metallic Replacement Cartridges
Merry X-Ray Corporation 3738 East Grand Road Tucson, Arizona 85716	X	X	X	X	X	X	X
New Orleans Silversmiths P. O. Box 52556 New Orleans, Louisiana 70150	X	X	X		X	X	X
Professional Equipment Service 1386 N.W. 29th Street Miami, Florida 33142	X		X		X		X
L. B. Spraque & Ned Bien 4236A Highway Avenue Jacksonville, Florida 32205	X	X	X		X		
Southwest Smelting & Refining Co. 1712 Jackson Street P. O. Box 2010 Dallas, Texas 75221	X	X	X	X	X	X	X
Texas Metals, Inc. 11351 Anaheim Drive Dallas, Texas 75229	X	X	X	X	X	X	X

APPENDIX F

GLOSSARY OF COMMONLY USED SILVER RECOVERY TERMS

Anode:.....A positively-charged electrode that attracts negative ions in the fixer and repels positive ions, such as silver ions.

Cathode:.....A negatively-charged electrode that attracts the positively-charged ions, such as the silver ions in the fixer.

Current Strength:..The amount of electrical current delivered to a square foot of cathode area. The higher the current strength, the faster the silver recovery.

Emulsion:.....The light sensitive gelatin coating on photographic films and papers.

Fixer: (Hypo).....A solution of sodium or ammonium thiosulphate in water. The thiosulphate extracts silver ions from the gelatin layer of the film.

Ion:.....An electrically charged atom, radical, or molecule, formed by the loss or gain of one or more electrons.

pH:.....A measure of the acidity of a solution, (in this particular case).

Silver
Concentration:.....The total amount of suspended silver in the fixer (hypo) stated in grams per liter or Troy ounces per gallon.

Sulfiding:.....The phenomenon of silver sulfide formation. This occurs when current strength is too high for the amount of silver near the cathode.

Troy (Weight):.....A system of weights used for precious metals. 12 Troy ounces equal 1 pound, rather than 16 ounces per pound.

BIBLIOGRAPHY

Annual Report of the Director of the Mint, for the Fiscal Year Ended June 30, 1969 (Washington D.C.: U.S. Government Printing Office, 1970).

The Argenta Series--Silver Recovery Systems (Los Gatos, California: Future Systems Inc., 1971).

Butts, Allison. Silver--Economics, Metallurgy, and Use (Princeton, N.J.: D. Van Nostrand Company, Inc., 1967).

Disposal of Photographic-Processing Wastes (Rochester, New York: The Eastman Kodak Company, 1969).

Forbes, Richard H. "Save the Silver," Printing Production, 100: 34-35, 57-59 (August 1970).

Hanson, Wallace. "The Day the Silver Runs Out," Popular Photography, 68: 61-63, 114-116, 149 (March 1971).

Hurd, John T. "How Much Profit Are You Flushing Down the Drain," Graphic Arts Monthly, 41: 42-45 (November 1969).

1971 Index to Kodak Technical Information (Rochester, New York: Eastman Kodak Company, 1970).

Kinsler, Milton C. "Start Mining That Darkroom Silver Lode," Printing Magazine, 93: 74, 77 (May 1969).

Kodak Bulletin for the Graphic Arts, No. 19 (Rochester, New York: Eastman Kodak Company, 1969), pp. 8-13.

Recovering Silver From Photographic Materials (Rochester, New York: The Eastman Kodak Company, 1969).

Recovery of Silver From Discarded Photographic Films and Papers (Rochester, New York: The Eastman Kodak Company, 1969).

"The Silver Drain," Modern Lithography, 39: 19-26 (January 1971).

"Silver in Photography," In-Plant Printer, 9: 42-44 (March 1969).

Silver Recovery with the Kodak Chemical Recovery Cartridge (Rochester, New York: The Eastman Kodak Company, 1968).

Tam, Stanley R. The Practical Guidebook of Photographic Silver Recovery (Lima, Ohio: States Smelting and Refining Corporation, 1969).